SNOW-FIELD AND GLACIER OLIGOCHÆTA FROM MT. RAINIER, WASHINGTON*

By Paul S. Welch

The material which forms the basis of this paper was collected on the snow-fields and glaciers of Mt. Rainier, Washington, during February, March, April, and June, 1915. Specimens first came to the writer through the courtesy of Professor Frank Smith, of the University of Illinois, to whom they had been sent by the United States Bureau of Biological Survey. The collections were made by Mr. J. B. Flett of the Longmire Ranger Station who later supplied the writer with six collections from the same region. The writer wishes to express his indebtedness to Mr. Flett for his continued interest and his many courtesies in furnishing carefully preserved material and in supplying data on the habits and appearance of the living worms.

Genus Mesenchytræus

Both of the species discussed in this paper belong to the genus *Mesenchytræus (Enchytræidæ)*, which, at the present time, includes almost sixty species and varieties, a few of which are of uncertain standing. Of this assemblage, twenty species and two varieties are recorded from North America. They are as follows, the type locality for each being given: *beringensis* Eisen (Bering Island, Bering Strait, Alaska), *beumeri* Mchlsn. (?) (Hamburg, Germany), *eastwoodi* Eisen (Hoods Peak, Sonoma Co., Calif.), *fontinalis* Eisen (Pine Ridge, Fresno Co., Calif.), *fontinalis* var. *gracilis* Eisen (Fresno Co., Calif.), *franciscanus* Eisen (San Francisco, Calif.), *fuscus* Eisen (Pit River, Calif.; No. Calif.), *fuscus* var. *inermis* Eisen (West Fork of Feather River and Goose Lake, Modoc Co., Calif.), *grandis* Eisen [Alaska (Sitka? or Juneau?)], *harrimani* Eisen (Kadiak, Orca, Metlakatla, Sitka, Yakutat, Unalaska, Alaska; Lowe Inlet, British Columbia), *kincaidi* Eisen (Ice-House Lake, St. Paul Island, Bering Sea, Alaska), *maculatus* Eisen (Popof

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Island, Alaska), *nanus* Eisen (Popof Island, Alaska), *niveus* Moore (Mt. St. Elias, Alaska), *obscurus* Eisen (St. Paul Island, Pribilof Group; Popof Island, Alaska), *orcæ* Eisen (Orca, Alaska), *pedatus* Eisen (Goose Lake, Alturas, Modoc Co., Calif.), *penicillus* Eisen (Port Clarence, Alaska), *setchelli* Eisen (Unalaska Island, Alaska), *solifugus* Emery (Muir Glacier; La Perouse Glacier, Alaska), *unalaskæ* Eisen (Unalaska, Alaska), and *vegæ* Eisen (Port Clarence, Alaska).

All but one of the above-mentioned species were originally described from North America and are not yet known to occur elsewhere. *Mes. beumeri* Mchlsn., a European species, has been doubtfully reported by Moore ('99, p. 141) from the vicinity of Philadelphia, Pa. He also reported an undescribed species of this genus from the same locality. The last American contribution to the knowledge of *Mesenchytræus* is that of Eisen ('05) in which most of the above-listed species are described. However, since that time new representatives of the genus have been reported from other parts of the world.

Mesenchytræus gelidus n. sp.*

(Plates XIV-XVI; Figs. 1-19)

Definition.—Length of alcoholic specimens, 21-32 mm., average about 24.7 mm. Diameter, 1.25 mm. Somites, 66-77. Color, dark reddish brown to almost black. Prostomium blunt, rounded, smooth. Head pore at tip of prostomium. Setæ sigmoid; all of same size and approximately uniform in length; in anterior part of body, 4-5 in lateral bundles, and 7-9 in ventral bundles; in posterior part of body, 3-4 in lateral bundles and 4-6 in ventral bundles. Clitellum on ¾XI-XIII, continuous around body. Two septal glands on IV/V and V/VI. Brain with width two to two and one-third times the length; anterior margin deeply emarginate, posterior margin almost straight, lateral margins diverging cephalad. Dorsal blood-vessel arises in XIV; cardiac body present. Nephridia with small, slender anteseptal part and large, irregular, compressed postseptal part; efferent duct arises from ventral surface

*A typographical error which the writer was unable to correct appears in the abstract of this paper (Welch, '16, p. 143). The name of this species appears therein as *gelicus* instead of *gelidus*.

of latter about mid-way of its length. Spermiducal funnel large, somewhat cylindrical, bent; length three to four times the diameter; collar present, variable, usually reflected or flaring, set off from body of funnel by distinct, broad constriction. Sperm duct 6-7 times length of funnel. Penial bulb large, somewhat globular; atrium globular but smaller than body of bulb; about twelve, elongate, finger-like, multicellular glands opening into ental extremity of atrium about entrance of sperm duct; two sets of glands within penial bulb. Sperm sacs extend caudad to XXXI–XXXV. Ovisac single, tubular, bifurcates in XVI; extends to XXXI–XXXV; contains sperm sacs. One pair of unusually developed spermathecæ; ectal opening laterad at IV/V, two inconspicuous groups of unicellular glands, surrounded externally by definite, light yellowish area; duct short, cylindrical, symmetrical, straight; two well-developed diverticula at ental end of duct, oppositely placed, elongate, slightly expanded at extremities; ampulla very long, usually terminating in IX–XI; devoid of connection with digestive tract; irregular, more or less unsymmetrical, constricted in regions corresponding to position of septa, caudal end usually dilated.

This description is based on twenty-seven sexually mature specimens. Many others of uncertain sexual maturity were examined in the study of external characters. The type and most of the paratypes are in the collection of the writer. Paratypes have also been deposited in the collection of the United States National Museum and in the collection of Professor Frank Smith.

The habitat of this species will be described in some detail in another part of the paper.

Affinities.—The determination of the affinities of this enchytræid is a matter of considerable difficulty, especially when the foreign species are considered. Many of the latter, recorded a number of years ago, are not described in sufficient detail to make possible a profitable attempt to discover relationships. Furthermore, the assemblage of species assigned to *Mesenchytræus* includes a number of poorly described ones, such as *Mes. armatus* Lev., *Mes. mencli* Vejd., and *Mes. montanus* Bret., the affinities of which cannot be judged either because of the failure to describe

a number of the essential details of structure or because of the use of sexually immature specimens. The validity of several foreign species seems to be questionable but, until they and other poorly described forms receive more intensive work, little can be done in the accurate determination of the synonymy. After a careful scrutiny of the literature dealing with the foreign species, the writer has not found any of them, as described, to closely approach *Mes. gelidus*.

Mes. gelidus belongs to the group of species having two diverticula on each spermatheca. This single point of agreement does not necessarily indicate close relationship and it is very possible that the convenient grouping of species on the basis of the number of diverticula is somewhat artificial. However, *Mes. gelidus* belongs to the group in which the spermathecæ are prolonged caudad through several somites and lack connection with the lumen of the digestive tract. It appears that at least five American species, namely, *Mes. harrimani* Eisen, *Mes. setchelli* Eisen, *Mes. franciscanus* Eisen, *Mes. obscurus* Eisen, and *Mes. maculatus* Eisen, are to be regarded as close relatives. They have been described in considerable detail and fairly satisfactory comparisons are possible.

Mes. harrimani differs from *Mes. gelidus* in having a length of more than twice the average of the latter; a larger number of somites; a smaller number of setæ in both lateral and ventral sets; brain square, not markedly wider than long; a longer and more slender spermiducal funnel; a much shorter sperm duct; and less compact nephridia, each possessing a distinct bladder-like chamber near the ectal opening of the efferent duct. Slight differences occur in the position of the clitellum and in the distribution of pigment. The penial bulb and associated structures are similar in some respects but a satisfactory comparison is prevented owing to a discrepancy in Eisen's description ('05, pp. 24-25) in which the following statement is made: "Atrium medium size, with about sixteen large gland-fascicles opening at the entrance of the atrium into the bulb." In the "Synopsis of species of Mesenchytræus" in the same paper (pp. 18-20) the following statement is made: "Penial glands, about 12 long atrial glands". Eisen's text figure No. 6 shows nine atrial

glands and another figure (Plate II, Fig. 4) shows fourteen. Both figures are, however, diagrammatic. No discussion of such variation occurs in the description and the writer is at a loss to know what interpretation to put upon the matter. Disregarding the atrial glands, the structure of the penial bulb, particularly the internal glands, differs from that of *gelidus*.

Mes. setchelli differs from *Mes. gelidus* in possessing a rounded brain with a decidedly convex posterior margin; in having the origin of the dorsal blood-vessel in XVIII; in having sperm sacs which reach only to XVIII; and in possessing only five atrial glands in connection with the penial bulb. Smaller differences exist in the character of the spermiducal funnel, nephridia, and in the details of structure of the penial bulb.

Mes. franciscanus differs from *Mes. gelidus* in the distinctly smaller number of setæ per bundle in both sets; in the origin of the dorsal blood-vessel in XVI; in the much longer and more slender spermathecal diverticula; and in the spermiducal apparatus which has a single, large, well-defined accessory gland in connection with the penial bulb, a sperm duct not longer than one and one-half times the length of the funnel, and distinctly sessile, globular, atrial glands. Minor differences exist in the position of the clitellum and in the finer structure of the penial bulb.

Mes. obscurus is distinguished from *Mes. gelidus* by the position of the clitellum on XII and XIII; the very long, slender, spermathecal diverticula; the very slender spermiducal funnel; the loosely constructed, three-lobed nephridia; and the possession of 16-20 atrial glands in connection with the penial bulb.

Mes. maculatus seems to be a close relative of *Mes. gelidus* but differs from it in the number of setæ per bundle in the lateral set; in the deltoid shape of the brain; in the spermathecæ in which the slender diverticula are not located at the junction of the duct with the ampulla and are much shorter than the former; and in the possession of three sets of internal penial bulb glands, one set consisting of multicellular glands.

External Characters

The body of *Mes. gelidus* is elongate, sub-cylindrical, smooth, and of about uniform diameter, except in the regions cephalad of

the clitellum and near the posterior end where there is a gradual tapering towards the extremities. In alcoholic specimens, there is a slight but distinct dorso-ventral flattening accompanied by a faint, shallow, mid-ventral, longitudinal depression which is present throughout the greater part of the body. However, since the writer has not had the opportunity of studying living material, no statement can be made concerning the constancy of these characters and there is the possibility that they are unnatural results incident to preservation and that the true form is a cylindrical one as is the case in many of the *Enchytræidæ*. The length, in preserved material, varies from 21 to 32 mm., the average of twenty-five sexually mature specimens being 24.7 mm. The maximum diameter, in the region of the clitellum, is about 1.25 mm. The segmentation is distinct in all parts of the body. The intersegmental grooves are narrow, shallow, and regular in outline, except in the vicinity of the extremities where they are broader, deeper, and more conspicuous, particularly on the cephalic end. The deepening of the intersegmental grooves in the regions of the extremities produces an antero-posterior convexity of the surface of intervening somites which elsewhere is uniformly plane. On the surface of each somite, midway between the margins, is a faint elevation or ridge which encircles the body, including the four setæ bundles. A number of the specimens show, in the middle region, a series of ruptures in the intersegmental grooves, thus producing whitish rings which consist of interruptions, more or less regular, of the cuticula and hypodermis, exposing the underlying muscle layers of the body-wall. Further discussion of these ruptures occurs in another part of the paper.

The number of somites varies from 66 to 77, the average of twenty-five specimens being 69. A few mature specimens were studied in which the number was as low as 50 but these were disregarded since there was some evidence of loss of somites and subsequent regeneration in the posterior region. The color of most mature specimens is, in general, deep reddish-brown to almost jet-black. The distribution of color is not uniform. The ventral surface is often of a slightly lighter hue and the anterior and posterior regions are invariably lighter in color. In occasional specimens,

the terminal somites are light yellow. Sometimes the black color predominates over almost the entire body. A few specimens were found in which a distinct, rather abrupt transition from also black to yellow occurred in the vicinity of LX but they are referred to above as displaying some evidence of regeneration, a possible explanation for the difference in color. The maximum intensity of the black color occurs dorsad and laterad, in the region behind the clitellum. An examination of the surface under magnification shows the universal presence over the body, save on the clitellum, of innumerable, minute, irregularly distributed, light yellow spots, which give the surface a flecked appearance. These microscopic areas are slit-like, the long axes predominantly extending in the direction of the circumference.

Certain, special, superficial areas show distinct color differences. The ectal opening of each spermatheca at IV/V is surrounded by a broadly fusiform area which occupies about one-half the width of the two adjacent somites and is rendered rather conspicuous by the contrast with the surrounding surface. The crescent-shaped mouth and the transverse slit-like openings of the penial bulbs and oviducts are surrounded by narrow but distinct, light yellow areas. On the ventral surface, beginning with VII, a pair of small, circular, widely separated, yellow spots occur on either side of the mid-ventral line and in close proximity to the cephalic margin of each somite. These are the ectal openings of the nephridia.

The clitellum occurs on ¾XI-XIII. Some slight variation in extent was noted but on completely mature specimens the above-mentioned limits hold. It is moderately thick, increasing, to a limited extent, the diameter of the body in that region. The distinct, uniform, yellow color renders it a conspicuous external character. It completely surrounds the body, no diminuation of thickness occurring on the ventral side. The surface is smooth and lacks the flecked appearance described for other regions of the body.

The head pore is distinct externally and located on the apex of the prostomium. The ectal opening has the form of a trans-

verse slit and is surrounded by a narrow, yellowish area. Dorsal pores are absent.

The setæ are distinctly sigmoid and arranged in fan-shaped bundles which are disposed in four longitudinal rows, two ventral and two lateral. The setæ of a bundle are all of approximately equal development. In the anterior part of the body, there are 4-5 setæ in the lateral bundles and 7-9 setæ in the ventral bundles. In the posterior part, there are 3-4 setæ in the lateral bundles and 4-6 in the ventral bundles. The setæ on XI are not specialized.

Internal Characters

Lymphocytes.—In the alcoholic specimens examined, the lymphocytes (Pl. XIV, Fig. 4) are scanty in the anterior region of the body but posterior to the clitellum they occur in some abundance. They vary in shape to some extent but, in general, are oval or elliptical. All lymphocytes are so heavily loaded with dark, non-staining pigment-granules that the cytoplasm is almost entirely obscured and frequently the nuclei are almost completely hidden.

Chloragog Cells.—Aside from the anterior five or six somites, the digestive tract is covered with chloragog cells (Pl. XIV, Fig. 5) for the greater part of its length. They are closely set together, usually elongated, and expanded at the free ends. In most of the specimens examined, these cells were heavily loaded with numerous, minute pigment-granules. In many instances, the amount of pigment present was almost sufficient to render the ectal portion of the cell unstainable.

Brain.—The brain (Pl. XV, Fig. 10) lies almost entirely in I, although in some of the specimens it extends slightly into II. It is easily dissected out *in toto,* thus facilitating the study of the organ as a whole. In all of the preparations, the shape and proportions are quite constant. The width is approximately from two to two and one-third times the length, an average measurement being: length, 0.132 mm.; width, 0.301 mm.; maximum thickness, about 0.011 mm. The anterior margin is deeply emarginate and slightly angular in character while the posterior margin is very slightly concave. From the rounded latero-caudal angles, the lateral margins diverge cephalad. Two pairs of supporting strands extend to the

body-wall, one arising from the anterior part near the emargination and the other from the posterior margin.

Nephridia.—The nephridia (Pl. XV, Figs. 14, 18) begin on VI/VII. Their shape varies somewhat in different regions of the body and in different specimens but, in general, the anteseptal part is composed of a nephrostome borne on an elongated, narrow pedicel. The postseptal part is an enlarged, irregular, compressed mass, the posterior end of which is reflected cephalad and gives rise to the efferent duct. In the large majority of the specimens examined, the nephridia are distinctly compressed and lie flat against the ental surface of the body-wall. Structurally, the body of the nephridium is of the usual mesenchytræid type. No evidence of a reservoir at the ectal end of the efferent duct was observed.

Spermiducal Funnel.—This organ (Pl. XV, Figs. 15-17) lies in the usual position in XI. The dimensions show limited variation but the length is commonly from three to four times the maximum diameter. A well-developed, variable collar is present. In all of the specimens examined, the funnels are bent in varying degrees, and the opening is directed caudad. The sperm duct is approximately 6-7 times longer than the funnel and extends caudad, usually to XIII/XIV. It is then reflected cephalad, extending into XII to unite with the penial bulb.

Sperm Sacs and Ovisac.—A large part of the cœlom posterior to the clitellum is occupied by the extensive sperm sacs (Pl. XIV, Figs. 1-2) and the single ovisac. They lie ventrad and laterad of the alimentary canal and are the most conspicuous of the internal organs. They are formed by very long caudal extensions of certain septa in the clitellar region. In the specimens examined, the delicate nature of these septa and the crowded condition of the internal organs in the clitellar region make the exact determination of the origin of the sperm sacs and the ovisac difficult and it is only by careful reconstructions of serial sections that the beginnings of these storage sacs can be followed. Septum XII/XIII continues caudad as a single, tubular outgrowth to XVI where it divides into similar halves, a right and a left, which lie on either side of the median line. The posterior termination, in the specimens exam-

ined, varies from XXXI to XXXV inclusive. Definite constrictions occur at intersegmental regions while between the latter distinct swellings are present. In sexually mature specimens, developing masses of ova occur in great quantities throughout the entire length of the sac.

Septum XI/XII continues caudad as two tubular outgrowths, one corresponding to each spermiducal funnel, which enter the ovisac and are completely contained within the latter and its branches. In XVI, where the ovisac divides, each sperm sac enters the corresponding branch of the ovisac and is coterminal with it, the variation in the position of the end being XXXI-XXXV. The sperm sacs also show constrictions and swellings which correspond to the segmentation. They fill approximately one-half of the lumen of the ovisac and, in sexually mature specimens, are crowded full of developing spermatozoa. The opening of each spermiducal funnel is directed towards, and is in close proximity to, the anterior opening of its corresponding sperm sac, in some specimens being partly contained within it. The sperm duct apparently lies entirely outside of these sacs.

A somewhat similar extensive provision for the storage of the developing reproductive cells has been reported previously in a few other species. Eisen ('05, pp. 25, 47, 49) found that in *Mes. harrimani* the sperm sacs extend "back some thirty somites" but made no mention of an ovisac; that in *Mes. fuscus* the sperm sacs are very large, "extending as far back as somite XXVII or further"; and that in *Mes. fuscus* var. *inermis* the sperm sacs extend to XXII and the ovisac to XXVIII. Other species are described in which sperm sacs and ovisacs are recorded as "extending far back" or by some other similar, indefinite statement. Many descriptions contain no mention of sperm sacs or ovisacs. Until such described species have been re-examined, it will not be possible to know whether or not these extensive sacs are peculiar to the American fauna.

Penial Bulb.—In general structure, the penial bulbs (Pl. XVI, Fig. 19) conform to the mesenchytræid type of Eisen. They present a noteworthy complexity of structure and agree in a number of respects with the same organs in certain Pacific Coast species.

They are attached to the ventral, ental surfaces of the body-wall in XII, one on either side of the median line. Each organ occupies a large part of the cœlom, having a total length, exclusive of the atrial glands, of about two-thirds the diameter of the body in that region. The maximum diameter slightly exceeds one-fourth of the transverse body-dimension. In the specimens studied, it was easy to dissect out these organs and to study them *in toto* as well as in serial sections.

Each organ is composed of two distinctly differentiated regions: (1) the globular atrium, and (2) the slightly elliptical body of the bulb. Superficially, the sperm duct unites with the ental apex of the atrium and is uniform in diameter from that point to the spermiducal funnel. About twelve, well-developed, finger-like, atrial glands are attached to the apex of the atrium near the union with the sperm duct. All are similar in shape and dimensions and extend freely into the cœlom. The attachments of these glands are not distributed uniformly about the apex of the atrium but are aggregated largely on one side.

The internal structure of the penial bulb is complicated and presents some interesting detail. In the completely retracted condition, the extension of the sperm duct forms at least one-half of the length of the bulb as a whole. The remainder of the organ is that part surrounding the penial bulb invagination. The continuation of the lumen of the sperm duct widens within the atrium to form a definite, spacious chamber, corresponding in contour to the external surface of the globular atrium. This chamber, at its ectal side, leads into an elongated lumen which expands slightly, forming another chamber, just entad of the penial pore. This expansion seems to correspond to the "penial chamber" described by Eisen ('05, p. 8). The penial bulb invagination is deep, bounded on the mesal side by a rather smooth wall, but on the opposite side two strong folds are present. It is lined throughout by a continuation of the external cuticula. The lining epithelium of the atrium differs from the corresponding tissue in the sperm duct in that the cells are elongated, reduced in transverse dimension, and lack cilia. The muscle-layer is in close proximity to the bases of these cells and while it varies somewhat in thickness and is interrupted at

intervals, it can be traced to its origin from the circular muscle-layer of the body-wall. The epithelium, at the penial pore, gradates into the hypodermis which forms the greater part of the lining of the penial bulb invagination. Structurally, it differs from the peripheral hypodermis only in the reduced length of the cells and the absence of the heavy, ectal zone of pigment, except at the entrance of the invagination and on the extremity of the first fold. The lateral portion of the bulb contains a large number of loosely associated muscle-strands which extend, in general, from the periphery towards the interior. The retractor muscle is formed largely by the union of strands from the circular muscle-layer of the body-wall with two other bands, each extending into one of the large folds which project into the invagination. The mesal side of the bulb, particularly near its base, also contains a loose meshwork of muscle-strands. In the ental half of the organ, a circular muscle-layer is present, exterior to and in contact with the longitudinal muscle-layer. The former is particularly well developed in the lateral half of the bulb. It seems probable that this circular layer is a continuation of the longitudinal muscle-layer of the body-wall. A very delicate peritoneum separates the muscle-layers from the cœlom.

Sections show that the atrial glands are composed of two very definite regions, a peripheral region and a central one. The peripheral region is constructed of large, somewhat cuboidal, distinctly nucleated, gland cells arranged in a single layer. The central region is composed of the extensions of the peripheral gland cells which evidently function as ducts. The gland cells take artificial stains intensively but the central region seems to have little or no affinity for them. These extensions of the gland cells composing the central region penetrate the wall of the atrium; extend beneath the muscle-layers, separating the latter from the epidermal lining of the atrial and "penial" chambers; and open into the penial bulb invagination on the surface adjacent to the penial pore.

Two sets of glands occur within the penial bulb. Many large unicellular glands of varying size and shape intermingle with the strands of the circular muscle-layer in the ental half of the organ. It has not been possible to follow out the extensions of these cells

and determine with what part of the lumen they are related. Another set of glands is present in the lateral side of the ectal half of the organ and are related to the penial bulb invagination. Small unicellular, fusiform, gland cells occur in the heavy folds of the wall, in close proximity to the hypodermis. Each gland has a very fine extension which is related to the hypodermis but the exact nature of this relation has not been determined. It seems probable that these prolongations extend to the surface of the cuticula.

Spermathecæ.—Among the prominent internal organs of the body is a pair of spermathecæ (Pl. XV, Figs. 7-8, 12-13) which first appears in V. These organs are greatly elongated, often extending caudad as far as XI and occupying the large part of the cœlom in that region. Each organ is composed of three distinctly differentiated parts, namely, duct, diverticula, and ampulla. The duct is straight, elongate, cylindrical, and slightly greater in diameter near its middle. The ectal opening is laterad in position in IV/V, slit-like, and surrounded on the external surface of the body by the distinctly light colored area already described. Two groups of unicellular glands are associated with the ectal opening, one on the cephalic and the other on the caudal side. The component glands of each group are elongate, club-shaped, and distinctly nucleated. These groups of glands are apparent only in sections and because of their small size may be overlooked in a casual examination. At the junction of the duct with the ampulla are two, smooth, club-shaped, oppositely situated diverticula, each of which is slightly longer than the spermathecal duct and is reflected caudad, parallel with the long axis of the ampulla. The bulk of the spermatheca is composed of the greatly elongated ampulla. It is characterized by a series of swellings and constrictions, the latter corresponding to the intersegmental grooves, and the whole ampulla often has a moniliform appearance. There is no connection of any kind with the digestive tract but the caudal, free extremity of the organ is an expanded sac, variable in form, and usually larger than any of the other distended portions of the ampulla.

The spermatheca shows some interesting variations. The duct and diverticula are comparatively constant in shape and size but the ampulla is variable. Commonly, the ampullæ in the same speci-

men are of equal development and approximately of the same shape but a number of specimens were examined in which one ampulla (Pl. XV, Figs. 12-13) was greatly elongated, extending into IX, while the corresponding one on the opposite side of the animal was reduced, extending through only one or two somites, and considerably different in shape. The usual position of the ampulla is parallel to and latero-ventral of the digestive tract but specimens were examined in which the ampullæ were somewhat contorted and partially wrapped around the digestive tract. It is possible that such a condition is responsible for the reduced size of one ampulla since in certain specimens the ampulla on one side had apparently exceeded the other in growth, had filled the available space on its side of the cœlom, and had become crowded to the opposite side while the ampulla of the opposite spermatheca had grown caudad until it came into contact with the other one and had evidently ceased development, resulting in its reduction in length. An examination of these reduced ampullæ *in situ* sometimes showed the free extremities in contact with the opposite ampullæ and doubled upon themselves, suggesting a crowding of parts in development.

The excellent state of preservation of the specimens made possible a study of the finer structure of the spermatheca. The external cuticula is reflected into the ectal opening and forms a complete lining for the lumen of the spermathecal duct, disappearing at the bases of the diverticula. The hypodermis merges into the lining epithelium of the duct which composes by far the greater part of the thickness of the wall. The cells are elongated, glandular in appearance, closely set together, and distinctly nucleated at their bases. They are longer in the middle region of the duct and are responsible for that position of the maximum diameter of the organ. At the ental end of the duct, these cells gradate rather abruptly into the lining epithelium of the diverticula. The circular muscle-layer of the body-wall forms the longitudinal muscle-layer of the duct for its entire length, diminishing in thickness at the bases of the diverticula. It has not been possible to determine whether the longitudinal muscle-layer of the body-wall is related to the spermatheca. Unicellular glands occur over the outer surface of the duct throughout its entire length.

The walls of the diverticula are composed of a lining of epithelium, constructed of cuboidal, closely set, glandular, distinctly nucleated cells, bounded on their ectal ends by a very thin muscle-layer which, in turn, is covered by a continuation of the above-mentioned peritoneum.

Structurally, the ampulla is composed of two regions, a short ectal portion adjoining the duct, and a very long ental part extending caudad. The lining epithelium of the ectal region shows numerous transverse folds, thus increasing its surface to a considerable extent. This epithelium usually has irregularly shaped, small, non-staining pigment-granules in the free ends of the cells. The muscle-layer is well developed in this part of the diverticula. Unicellular glands occur exterior to the muscle-layer and are bounded at their outer ends by the peritoneum. In the remainder of the ampulla, the wall is greatly reduced in thickness so that the layers are difficult to distinguish. A thin lining epithelium and a delicate peritoneum are present and there are some hints of the presence of a muscle-layer, the exact character of which could not be determined. Small, scattering, irregular thickenings occur on the inner surface of this region.

The contents of the spermathecæ present some interesting features. In all of the sexually mature specimens examined, the spermathecæ contain spermatozoa which have a definite distribution in the organ. No spermatozoa were found in the duct but the diverticula almost invariably contained them, each mass having a definite and constant relation to the epithelial lining. The heads are all in contact with the lining of the diverticulum and the tails extend out into the lumen. The meaning of this arrangement is not clear. Spermatozoa are almost constantly absent from the ectal portions of the ampulla but, in the long, expanded part, surprising quantities, crowded into large masses, are present in the lumen and are not related to the wall in any way.

The striking structural feature of the spermathecæ is the unusual size. It appears from a study of the literature on *Mesenchytræus* that greatly enlarged and elongated spermathecæ, such as the type just described, have been found only in American species from the Pacific Coast. Eisen ('05) described such organs for the

first time in the following species: *Mes. harrimani, Mes. setchelli, Mes. franciscanus, Mes. obscurus, Mes. maculatus, Mes. vegæ,* and *Mes. orcæ.* As descriptions stand at present, it appears that in this large genus only a small group of species possesses this particular type of spermatheca. Eisen ('05, p. 15) makes the following statement in this connection: "There is some little reason to suspect that this enlargement of the spermathecæ in this genus may have been overlooked in some species, and that some spermathecæ which have been described as short and as immediately connecting with the intestine, in reality are greatly prolonged posteriorly. The part adjoining the diverticles is always narrow and closely approaches the intestine. This peculiarity causes it to tear readily and I am satisfied that such torn spermathecæ have been considered as entire." Whether Eisen's speculations are true remains to be proved but since some of the descriptions of foreign species are very meager, unsatisfactory, and evidently made without careful dissection of specimens or the study of serial sections, it is possible that this type of spermatheca is not quite as unique as it now seems. However, since the spermathecæ have long been used as a taxonomic character and therefore called for special attention, it would appear that the number of cases in which such exceptionally large organs would be overlooked must, at best, be quite small. An inspection of the above list of species possessing such spermathecæ shows that these forms are all Alaskan in distribution, save *Mes. franciscanus.* It might be suspected that greatly enlarged and prolonged spermathecæ are characteristic of species inhabiting cold regions but *Mes. falciformis* Eisen, *Mes. fenestratus* (Eisen), *Mes. primævus* Eisen, and others are found in the arctic regions of the Old World and yet do not possess this peculiarity. Likewise, *Mes. solifugus* Emery and *Mes. niveus* Moore, found in frigid conditions in Alaska, have spermathecæ of the ordinary enchytræid type.

Pigmentation.—Examination of sections of the various regions of the body shows that the color described in foregoing pages has its basis in dark, brownish, non-staining pigment-granules which occur in marked abundance in the body-wall and certain internal organs. The hypodermis bears the principal load, the pigment being distributed through this whole layer. It occurs chiefly in the

outer ends of the hypodermal cells but may be scattered all through them. Pigment-granules are present in varying amounts in the following internal organs: (1) lymphocytes; (2) chloragog cells; (3) epithelial lining of the ectal, folded end of the spermathecal ampulla; (4) ectal portion of the hypodermal lining of the penial invagination; (5) setigerous glands; (6) lining of the buccal cavity and the pharynx; and (7) ectal ends of the efferent nephridial ducts. Of the above-mentioned internal structures, the lymphocytes and the chloragog cells contain the largest amounts of pigment. Granules do not seem to occur in connection with the nervous systems as is the case in *Mes. solifugus*.

BIOLOGICAL NOTES

The only recorded observation of "snow worms" on Mt. Rainier which the writer has been able to find is given by Moore ('99,p. 142): "In a letter Prof. Russell adds the interesting information that he has observed similar worms on the snows of Mt. Rainier, Wash., thus indicating for them a wide distribution."

All of the information concerning the living form has been supplied by Mr. J. B. Flett, who, as stated before, furnished the writer with the material on which this paper is based. Sexually mature specimens were collected from February 23 to April 5. Whether this represents the seasonal period of sexual maturity is not known. Between the above-mentioned dates, these worms occurred abundantly on the snow-fields of Mt. Rainier, at an elevation of from 2700 to 5600 feet. They also occurred on the snow on the mountain slope in a dense forest of fir and hemlock. These worms have not thus far been found on ice nor on the graciers though they occur on the snow below the ice front and outside of the lateral moraines of Nisqually Glacier. The snow on which they were found is not permanent through the entire season but melts with the coming of summer and it therefore appears that a part of their life history must be spent on or in the ground. During midwinter when the temperature is very low, they are inactive and do not appear on the surface of the snow. Appearance at the surface accompanies the rising temperature in the spring and their activity becomes noticeable when the snow is beginning

to melt. When placed on hard packed snow during their active period, they are able to bore down through it at will. Under conditions of softening snow, they exhibit a rather efficient locomotion. When taken in the hand, they perform lively squirming movements for a time but soon relax and become quiet. Blue jays and several other species of birds prey upon these worms, picking them off the surface of the snow.

There is the possibility that these enchytræids undergo a color change during the first few days of their appearance. The first specimens, which were collected January 7, are very light yellowish in color and show no evidence, externally or internally, of pigment. Since these specimens are sexually immature, specific identification is not possible but they seem to be the species under discussion. As already stated, the sexually mature form is very dark in color and bears a conspicuous amount of pigment. Mr. Flett is of the opinion that, since the light colored specimens only appear very early in the season and since dark specimens of similar size appear later in the same localities and in approximately the same numbers, this difference in color is probably not a species difference but rather a life history difference in the development of the same species. None of the light colored specimens examined by the writer have been sexually mature but all of the dark colored individuals have either been completely mature or very close to complete sexually maturity. The evidence thus far is circumstantial only and does not justify any definite conclusions. It may be mentioned in this connection that Moore ('99, p. 135), quoting Mr. Bryant, reports what seems to be a similar color change in *Mes. solifugus*.

Nothing definite is known concerning the food of these snow-worms. Mr. Flett reports that the snow over which these enchytræids crawl has a red color, due to a minute, unicellular plant, which, in his opinion, serves as food for the worms. The writer made some examinations of the material contained in the alimentary canal of these worms, and found what seems to be microscopic algæ composed of very minute, globose cells, containing greenish and reddish colors, occurring singly or in clusters, and having the appearance of *Pleurococcus*. This material occurs

in considerable quantity in the digestive tract and offers evidence leading to the conclusion that the minute snow algæ constitute at least a part of the food of these worms.

A number of the collections made by Mr. Flett contained representatives of the associated animal life. Insects belonging to seven orders, Collembola, Hemiptera, Plecoptera, Coleoptera, Diptera, Lepidoptera, and Hymenoptera (several species in five of the orders), one species of Gastropoda, and three species of Araneida were found in the same habitat with the snow-worms. The Collembola (*Isotoma* sp.) occur in enormous numbers, especially on the snow below the glacier, making it black in appearance. In this respect the situation resembles that described by Moore ('99, p. 136) for *Mes. solifugus* which had great quantities of a collembolan, thought to be *Achorutes nivicola,* associated with it. All of these associated animals are black or very dark, except one species of spider and one species of Hemiptera, both of which are largely of a dark red color.

Mesenchytræus solifugus rainierensis n. var.

(Plate XVII, Figs. 20-26)

A collection from the upper snow-fields of Mt. Rainier, made on June 17, 1915, by Mr. Flett, contained seventy-five specimens of any enchytræid, blackish in color but smaller than *Mes. gelidus.* A thorough study of this material, which is in good histological condition, showed that it must be regarded as *Mes. solifugus* Emery. However, several structural characters fail to correspond to the descriptions of Emery ('98a, '98b, '98c, '00a, '00b), Moore ('99), and Eisen ('05). Previously known material of *Mes. solifugus* could not be secured for study but a very careful comparison of the characters of the material from Mt. Rainier with the published descriptions indicates that the deviations are apparently not sufficient to justify the separation into another species. Nevertheless, the variations are so constant that the writer feels convinced that it must be considered as a new variety.

Mes. solifugus was first described by Emery under the name *Melanenchytræus solifugus,* from specimens collected by Filippi on Malaspina Glacier, at the base of Mt. St. Elias, Alaska. The fol-

lowing year, Moore ('99) published a more extended account of the same species from material collected by Mr. H. C. Bryant, also on Malaspina Glacier. His paper contained not only the results of a careful anatomical study and a quoted account from Mr. Bryant of the habitat and the activities of these annelids, but also an interesting discussion of their relation to the peculiar habitat, with special reference to temperature and light, and an account of the possible function of the dense pigmentation. In the same material, Moore found another form which he described under the name *Mes. niveus.* He also rightly placed *Melanenchytræus* as a synonym of *Mesenchytræus.* Eisen ('05) published a short account of *Mes. solifugus,* specimens of which were collected by Professors T. Kincaid and W. E. Ritter during the Harriman Alaska Expedition on Muir Glacier and on La Perouse Glacier. It thus appears that up to the present account *Mes. solifugus* has been known only from glaciers in a very limited region of Alaska.

Definition.—Length, 12-18 mm., average about 15 mm. Diameter, about 0.52 mm. Somites, 51-60, average 55. Color, very dark brown to black. Prostomium rounded, smooth, blunt. Head pore at tip of prostomium. Setæ sigmoid, abruptly bent at distal ends; uniform in size and shape; in anterior fourth of body, 2 setæ, rarely 3, per bundle in lateral rows; in remainder of body, 1 seta, rarely 2, in lateral rows; in anterior third of body, 2-4 setæ, usually 3, per bundle in ventral rows; 2 setæ per bundle in ventral rows in remainder of body. Clitellum absent. Brain but very slightly longer than wide; anterior margin deeply emarginate, posterior margin shallowly concave, lateral margins approximately parallel. Origin of dorsal blood-vessel in XIII-XIV; small cardiac body present. Nephridia with small, slender, anteseptal part and large, irregular, lobate postseptal part; origin of efferent duct on ventral surface of latter very near posterior end. Spermiducal funnel moderate, cylindrical, tapering slightly towards origin of sperm duct; length about three times the maximum diameter; collar absent. Sperm duct very long, extending caudad within ovisac to XX; masses of coils in XIII-XIV; diameter uniform throughout. Ovisac extending from XII/XIII to XX, bifurcating in XIII or XIV. One pair of sperm sacs extending from XI/XII to about

XV; within ovisac. Penial bulb large, subglobular; well-developed, fusiform atrium with five atrial glands; numerous groups of multicellular glands within bulb. Spermathecæ confined to V; duct short, cylindrical, numerous unicellular glands externally; ampulla but little greater in diameter than duct, elongate, tapering slightly entad and uniting in posterior part of V with lateral aspect of digestive tract; two opposite, elongated, cylindrical diverticula reflected caudad.

The description is based on twenty-seven sexually mature specimens. Forty-eight other specimens of uncertain sexual maturity were examined in the study of external characters. The type and most of the paratypes are in the collection of the writer. Paratypes have been deposited in the collection of the United States National Museum and in the collection of Professor Frank Smith.

The habitat of this species will be described in another part of the paper.

External Characters

The body is elongate, cylindrical, smooth, and uniform in diameter except at the extreme anterior and posterior ends where there is a slight but gradual tapering. The length of the alcoholic specimens varies from 12 to 18 mm., the average length of twenty-seven sexually mature specimens being approximately 15 mm. The diameter varies from 0.47 to 0.63 mm., the average being about 0.52 mm. Except in the extreme anterior region, the external segmentation is indistinct, the surface being smooth and the intersegmental grooves difficult to detect. As in *Mes. gelidus*, external examination shows the presence of ruptures in some of the intersegmental grooves, thus producing whitish rings between somites. Longitudinal sections show that these ruptures are breaks in the cuticula and hypodermis and the underlying muscle-layers are thus exposed, producing the whitish band. Such ruptures are present in almost every specimen sent to the writer and occur uniformly in the middle region of the body, the anterior and posterior ends only being invariably free from them. No information is available at present concerning the origin of these interruptions. Moore ('99, p. 126) reports a similar feature in some of the specimens

of *Mes. solifugus* which he examined. He also states that Mr. Bryant, the collector who secured the material on Malaspina Glacier, Mt. St. Elias, and furnished data on the living animal, informed him that these white or yellow bands "were present when the worms were collected". On a later page (p. 135), Moore quotes directly from an account by Mr. Bryant, a part of which is as follows: "Some of the specimens I obtained had also distinct whitish bands around their bodies." From this account it might appear that these light bands occur in the living worms. Whether it is true of *Mes. gelidus* and *Mes. solifugus* var. *rainierensis* remains to be discovered. It seems unlikely, from an examination of the available material, that these interruptions are normal. Longitudinal sections show ragged edges of tissue about these interruptions, a fact which seems to constitute evidence against such a view. The appearance suggests the killing and preserving operations as the cause, although none of the specimens showed signs of extreme contortion or severe treatment.

The external surface of each somite is smooth and free from ridges, secondary constrictions, or striations of any sort. The number of somites varies from 51 to 60, the average being about 55. Except at the extreme anterior and posterior ends, the somites are of approximately uniform width. The color of the entire body is very deep brown to black, except for the above-mentioned whitish bands between somites. To the unaided eye, the specimens are black but under magnification, using transmitted or reflected light, they are a deep, rich brown. The distribution of the color is almost uniform throughout the body. Specimens, cleared and mounted *in toto*, show on the surface, except on XI–XIII, innumerable, minute, polygonal areas, usually hexagonal, each of which has a long and short dimension, at right angles to each other, the former extending in the direction of the circumference of the body. Each area contains in its center a light, oval spot.

Certain special, external areas are distinctly lighter in color than the surrounding surface. The tip of the prostomium and the lateral parts of the groove 0/I are yellow and offer contrast with the adjacent parts. The ectal opening of the spermatheca in IV/V is surrounded by an ovate, yellowish area which, however, is not as

distinct as in *Mes. gelidus*. The posterior end of the last somite and the immediate vicinity of the penial bulb invaginations are also much lighter than surrounding parts.

These specimens lack the conspicuous, elliptical, swollen areas about the ectal openings of the spermathecæ which Moore ('99, p. 125; Figs. 1, 2) found in the Malaspina Glacier specimens. Such areas are represented only by the lighter color in the immediate vicinity of the openings described above. Emery and Eisen make no mention of these areas.

A distinctly differentiated clitellum seems to be absent. The region of XI–XIII differs from the adjacent somites only in the obscurity of the intersegmental grooves and the slightly increased body diameter in that part containing the penial bulbs. Transverse and longitudinal sections of sexually mature specimens show no increase in the thickness of the hypodermis. The apparent absence of a clitellum causes some difficulty in distinguishing sexually mature individuals in superficial examination but in the material on which this paper is based it has been found that all specimens showing distinctly protruding penial bulbs are sexually mature. The uniform absence of a differentiated clitellum might cast some doubt, at first thought, upon the sexual maturity of all of the specimens but serial sections and dissections have demonstrated the presence of spermatozoa in the spermathecæ, developing ova and spermatozoa in the storage sacs, and well developed ovaries and testes, thus furnishing proof of sexual maturity. Moore ('99, p. 125) reported that "In none of the specimens examined (about twenty in number) is the clitellum very distinctly developed, but on the contrary is thin and scarcely extends beyond the limits of the twelfth somite." Eisen ('05, p. 59) found it "probably confined to XII."

The head pore is distinct and located very near the tip of the prostomium. The external opening is slit-like in appearance, transverse in position, and surrounded by a very narrow, yellowish area.

The setæ are distinctly sigmoid and arranged in fan-shaped bundles, two lateral and two ventral. Those of a bundle are of approximately equal development. Anterior to the penial bulb invagination, the lateral bundles contain 2 setæ, very rarely 3;

posterior to that region, they contain 1 seta, very rarely 2. Anterior to the vicinity of XX, the ventral bundles contain 2-4 setæ, usually 3; posterior to that region, they contain 2 setæ. The setæ are somewhat distinctive in the very abrupt bend at the distal, exposed end (Pl. XVII, Fig. 24). The proximal end is broadly curved and deeply imbedded in the body-wall. A comparison with the descriptions of Moore and Eisen shows that the number of setæ per bundle which they report is greater than has been found in the Mt. Rainier material. In the latter, the writer has found but a single bundle which contained five setæ. It is not possible to determine whether the abrupt bend at the distal end of each seta described above is a characteristic only of *rainierensis* since Moore ('99, p. 126) states that in his Alaskan specimens "The setæ have the form usual in the genus, being feebly sigmoid and arranged in fan-shaped bundles, but are mostly imperfect, owing to the points being worn or broken off." He also reports that "Enlarged setæ are found in the ventral bundles of XI; these are about one-third longer and much thicker than the others." Such enlarged setæ have not been found in the specimens from Mt. Rainier. Emery ('00b, p. 225, Fig. 10) states that "The *chactae* are slightly sigmoid, more markedly bent at their apical end (Fig. 10). They are about a third longer in the posterior half of the body than in the anterior segments, as it appears by comparing Figs. 12 and 13. Each bundle consists of four nearly equal chaetae. The ventral bundle is absent in the 12th (clitellar) segment, which receives the opening of the sperm-duct." From this description it might appear that the setæ resemble closely those of *rainierensis* but the figure which accompanies Emery's description portrays setæ quite different from those found in the Mt. Rainier specimens. Instead of being very slender, approximately uniform in diameter, distinctly sigmoid, broadly curved at the proximal end, and abruptly curved at the distal end, they are short and very stout, having, in the posterior bundles, a diameter of one-sixth the length. The diameter increases from the distal end to the opposite extremity which is almost straight. The distal end is very acute.

Internal Characters

In many respects, the internal anatomy corresponds to that described, by previous observers, in the Alaskan form and for that reason only new data and the features which present differences will be discussed.

Brain.—Dissections and frontal sections show the brain (Pl. XVII, Fig. 22) to correspond, in a general way, to the accounts of the same organ in Alaskan specimens. It resembles more closely the figure and description given by Moore, differing in being a little longer than broad and in having the posterior margin distinctly but shallowly concave. However, these are minor differences. It also resembles the figure given by Emery ('00b, Fig. 2) except that the concavity of the anterior margin is much deeper. A typical measurement is as follows: maximum length, 0.137 mm.; maximum width, 0.129 mm.; maximum thickness, 0.043 mm. A supporting strand extends latero-caudad from each latero-caudal angle to the body-wall.

Dorsal Blood-vessel.—According to the previous descriptions of *solifugus,* the origin of the dorsal blood-vessel occurs in XII. In the Mt. Rainier specimens, this vessel becomes distinct from the perivisceral blood-sinus in the posterior part of XIII or the anterior part of XIV. In none of the specimens examined did it arise in XII. An inconspicuous cardiac body is present.

Septal Glands.—In position, the septal glands agree with the description by Moore ('99, p. 127) but cannot strictly be called "large". Eisen ('05, p. 59) found the "Septal glands small" but the position is not indicated. Of the two indefinite terms, the latter is more nearly correct for the specimens studied by the writer.

Emery ('98a, pp. 110-111) includes the following statement in his original description of *solifugus*: "Nei segmenti 4-8 la cavita viscerale è in gran parte occupata da ghiandole unicellulari, i cui lunghi e sottili condotti sboccano all' esterno in vicinanza dei gruppi ventrali di setole." Michaelsen's description of *Mes. solifugus* ('00, p. 87) contains the following: "Liebeshöhle des 4.-8. Segm. von grossen einzelligen Drüsen erfüllt (Kopulationsdrüsen?), die in der Nähe der ventralen Borstenbündel ausmünden." This statement, evidently taken from Emery, contains the tentative suggestion

by Michaelsen as to the character of the glands. Emery ('00b, pp. 226-227) in his later and more complete paper, describes these glands as follows: "In the segments 4-8, the most part of the body-cavity is filled by *unicellular glands* (Fig. 11 gl); their very thin excretory prolongations form numerous threads directed towards the ventral side, which can be easily followed on the sections to the sides of the ganglion chain. Their thinness and flexuous course make it difficult to follow them to their end on the surface of the skin. I believe that they converge towards the bundles of chaetae of the ventral series. As Mr. Michaëlsen writes me, these glands may be regarded as morphological equivalents to those gland-cells which in other Enchytraeids are related to the chaetae of the genital segments. In Melanenchytraeus, I don't think that these glands have any relation to the function of reproduction, because I find them no less developed in immature specimens." No mention of such special unicellular glands is found in the descriptions of Moore and Eisen and the writer has found no evidence of them in his material. Since the position of these unknown glands coincides with the position of the septal glands, as described by Moore and as found by the writer in Mt. Rainier specimens, it might be suspected that the two have been confused. Emery ('00b, Fig. 11) figures these glands as they appear in a longitudinal section of the body and although the component cells are not associated in close, compact masses, they are aggregated into rather loosely associated groups and columns with their prolongations approaching each other and extending in the same directions. The appearance of the whole very strongly suggests loosely constructed septal glands and since Emery worked with a very few sexually mature specimens which were not in the best state of preservation, the writer is inclined to suspect these masses of "unicellular glands" of being the usual series of septal glands.

Nephridia.—The nephridia (Pl. XVII, Fig. 25) agree closely with previous descriptions. A well-developed, ciliated nephrostome, borne on a slender base, comprises the anteseptal part. The postseptal region is enlarged, somewhat lobate, and slightly compressed. The structure of the interior is of the usual mesenchytræid type. The efferent duct arises from the ventral surface of the postseptal

part near the caudal end. In the specimens examined, there is considerable variation in the size and shape of the nephridia in different regions of the body but the general structure is fairly constant. The first pair is located on VI/VII. Moore ('99, p. 127) found nephridia "in every somite posterior to VII." No nephridia have been found on XI/XII and XII/XIII in the Mt. Rainier specimens.

Lymphocytes.—Lymphocytes are very scanty, in some specimens almost absent. A few scattering cells occur in the anterior region and occasional ones more caudad. They are small, elliptical, nucleated, and contain pigment-granules.

Spermiducal Funnel.—The spermiducal funnels (Pl. XVII, Fig. 23) depart somewhat from Moore's descriptions of Alaskan specimens of *solifugus*. Instead of being constricted at the middle and bent upon themselves so that the free end is directed caudad, they show only a slight diminution in diameter and a slight bend at the middle so that the free end is directed cephalo-dorsad. A much greater disagreement is found when comparison is made with Emery's figure ('00b, Fig. 16) of the funnel which is represented as a very short, funnel-shaped organ which is broader than long. However, Emery states that his figure was drawn from a reconstruction. The length is about three times the maximum diameter, a typical set of measurements being as follows: length, 0.344 mm.; diameter, 0.113 mm. The collar is entirely absent.

Sperm Duct.—The sperm duct is very long and of approximately uniform diameter. Because of its coiled and contorted condition, the exact determination of its length has not been possible. It extends from the end of the spermiducal funnel into the ovisac; forms contorted masses in XIII and XIV; continues caudad within the ovisac to XX; thence is reflected cephalad to XII to unite with the atrium. Throughout the entire course it is characterized by numerous coils and curves. Its extent is represented by the combined length of sixteen somites plus an allowance of the length of several somites to compensate for the contortions. Except for a very small part at the end of the spermiducal funnel and at the union with the penial bulb, the entire duct is contained in the ovisac, and does not, according to the writer's observations, enter either of the sperm sacs. Moore ('99, p. 129) found that, in his material,

the sperm duct on the right side lies within the ovisac and extends to the region of XVIII, but the one on the left side lies free in the body-cavity, extending also to the region of XVIII. Eisen's description contains no account of these ducts.

Sperm Sacs.—The sperm sacs are a pair of caudal evaginations of XI/XII, one on each side of the median line, which lie latero-ventrad of the digestive tract and extend to XV or XVI. In the specimens examined, they are rather small, but both are of about equal development. Both lie within the ovisac and both contain masses of developing spermatozoa. The structure of the walls of these sacs is identical with that of the septa.

Moore ('99, p. 128) found a different condition in Alaskan material. The sac on the right side is almost rudimentary, extending only into XII, while the one on the left side is well developed, extends caudad to XX, and is apparently not contained within the ovisac. Other descriptions do not include data on the structure and relations of these sacs. Allowing for a liberal variability, such differences seem rather large for intra-species variation.

Ovisac.—The ovisac is formed by the caudal outgrowth of XII/XIII. It arises as a single, well-developed sac and extends caudad, ventrad to the digestive tract, to the posterior part of XIII or to XIV where it bifurcates, forming two branches, one on either side of the median line, which extend to the vicinity of XX. There is some variation in the length since specimens were examined in which the caudal terminations were in XXII, while in others they were in XIX. As stated above, the ovisac contains the sperm ducts and the sperm sacs. In addition, it contains masses of developing ova. Here, again, is an interesting divergence from the condition described by Moore ('99, pp. 129-130) who found, in the Alaskan material, that the ovisac is single throughout its entire length and contains only the right sperm duct and the masses of developing ova. The length, however, is very similar in both cases.

Penial Bulb.—In the general plan of structure, the penial bulb (Pl. XVII, Figs. 20, 26) agrees with the description by Eisen ('05, p. 60) for Alaskan specimens. However, a number of differences exist in some of the finer structural detail. The whole

organ is of the mesenchytræid type as described by Eisen ('05, p. 7) and consists of three sets of structures, viz., the penial bulb proper, the atrium and its associated parts, and the accessory glands. The whole organ is conspicuous in size so that both bulbs occupy the greater part of the cœlom in that region.

The penial bulb proper is situated on a deep invagination which, in transverse section of the body, is slit-like but in longitudinal section appears as a narrow channel leading, at its inner extremity, into an expansion which takes the form of a chamber, narrow in dorso-ventral dimension but much wider in transverse dimension. This inner chamber caps the ental part of the invagination like the top to a mushroom. Structurally, the wall of the invagination is essentially a continuation of the body-wall. The ectal end of the sperm duct connects with the inner, expanded chamber. The body of the bulb is composed of (1) a large number (over twenty-five) of multicellular glands, (2) scattering unicellular glands, (3) a large number of muscle-strands, and (4) the ectal end of the sperm duct. The multicellular glands are pear-shaped, the expanded ends being entad of the invagination. Each is composed of a number of gland cells aggregated in the expanded ends and a narrow, tapering extension, composed of the elongated ends of the gland cells, which connects with the penial invagination. None of these glands opens into the sperm duct. The unicellular glands are sessile, very inconspicuous, and are scattered singly about the invagination into which they apparently open. They are the only glands which occur laterad of the invagination. In the interior of the bulb, muscle-fibers extend in different directions. They lie between the various glands and many of them are attached to the wall of the invagination. They vary in size from very fine threads to rather strong strands. The ectal end of the sperm duct, which is contained within the body of the bulb, has the usual structure except that it is surrounded by a very strong, longitudinal muscle-coat which is apparently derived from the longitudinal muscle-layer of the body-wall.

Within the penial bulb but near its ental surface, the sperm duct begins to expand into the atrium so that a small portion of the ectal part of the latter is included within the envelope of the

bulb. The atrium is a stout, fusiform organ, about 0.3 mm. long and 0.13 mm. in maximum diameter. Its histological structure is very similar to that indicated in Eisen's figure ('05, Pl. VIII, Fig. 1), except that the epithelium on the surface does not seem to be as distinct and thick. At the ental end of the atrium is a set of about five large, club-shaped, multicellular atrial glands, arranged in a whorl. These glands extend into the cœlom and are conspicuous organs in sections of that part of the body.

A number of large, multicellular, pear-shaped, accessory glands are present. They lie just outside of the envelope of the bulb and open into the invagination, commonly at its origin. In general structure, they resemble the multicellular glands within the penial bulb. The surrounding envelope is very delicate and it is difficult in some of the specimens to determine just how many of the glands at the edge of the bulb are to be classed as accessory.

The structure of the penial bulb and its associated parts in *solifugus* has been briefly described by Moore ('99, p. 129) and Eisen ('05, pp. 59, 61) as it occurred in the Alaskan material which they examined, and a comparison with the Mt. Rainier specimens is of interest. Moore states that "Before entering the atrium in somite XII the recurrent limbs of the sperm ducts expand into narrow fusiform sacs (.....), having glandular, epithelial and muscular walls, which receive the ductules of a group of unicellular spermiducal glands. This structure probably serves to form and eject the spermatophores. A narrow curved duct, which is also provided with some unicellular glands, perforates the mesial wall of the atrium and opens into its lumen. Unlike the remainder of the male efferent apparatus, the atrium (.....), is, in part, of ectodermal origin, as is indicated by the pigmented lining epithelium. It is a spheroidal thick-walled partly eversible sac, with an internal cavity having a mushroomlike shape in the retracted organ. Its walls are composed of a cuticle-covered, rather deep, pigmented and perhaps glandular epithelium, surrounded by a thick muscular layer in which the fibres are partly longitudinal, but largely radial, especially about the place of entrance of the sperm duct. A number of groups of unicellular glands are attached to the organ, and probably empty into its lumen."

At first sight, it might appear that a radical difference exists between the structure of the Alaskan and Mt. Rainier specimens. In the first place, a difference in the use of terminology is evident. Moore applies the term *atrium* to the structure which the writer and others call the *penial bulb,* and speaks of the expansion of the sperm duct just entad of the bulb as "narrow fusiform sacs". The writer follows Michaelsen ('00, p. 9) and Eisen ('05, p. 4) in using the term *atrium* to designate the enlargement of the sperm duct which is situated just entad of its union with the penial bulb. Apparently, Moore regards the atrial glands and the multicellular glands within the penial bulb as "groups of unicellular glands" rather than multicellular glands as described by the writer. If this interpretation of Moore's description is in error, then the structure of the penial apparatus in the Alaskan specimens is very different from that described in the present paper. No distinction is made in the above-quoted description between the penial glands within the bulb and the accessory glands.

Eisen ('05, pp. 59, 61) describes the penial apparatus in *solifugus* as follows: "A large atrium in which opens about eight atrial glands of large size. Many large accessory glands open along the base outside of the penial bulb. About fifteen penial glands inside the penial bulb. . . . . The accessory glands, which are characteristic, open along the base of the penis outside of the bulb. They are long and of trefoil shape, with enormous long narrow ducts." It will be noted that Eisen found a greater number of atrial glands in his material. Furthermore, the accessory glands are evidently much longer and the number of penial glands in the bulb greater than in *rainierensis.*

Emery ('00b, pp. 227-228, Fig. 16) describes the penial apparatus as follows: "The last tract [Sperm duct] forms a spherical bulb (*a*), but before reaching it the tube presents a fusiform swelling (*c*), whose wall is very thick and made of long cells, directed radially on the transverse section, the lumen being not widened. Bundles of prostatic (spermiducal) glands (*b*) are related to the bulb; another little group of glands (*e*) lies around the tube, above its fusiform thickening." Some difficulty is experienced in interpreting this description, expecially when the figure is con-

sulted. The spherical body of the bulb and the atrium agree with the other descriptions but the "prostatic glands" are represented as large, rather numerous, lobular organs which lie out in the body cavity, opening into the penial bulb much as do the corresponding organs in *Mes. gelidus*. The other group of glands referred to is of uncertain identity, judging from either the description or the figure. Emery's figure was made from the reconstruction of a series of sections and is possibly not fully dependable, although it seems improbable that a mistake could have been made in the matter of so large a group of glands as those which he calls prostatic. Assuming that his observations have been fairly correct, the penial apparatus differs from those described by Eisen and Moore as well as from *rainierensis*.

Spermathecæ.—The spermatheca, in all of the specimens examined, consists of (1) a short, stout, cylindrical duct, covered externally, in part, by numerous attenuated, unicellular glands, (2) two almost oppositely placed, elongated, cylindrical diverticula which are directed caudad, and (3) an elongated, slightly curved ampulla which decreases slightly in diameter towards the ental end and joins the digestive tract independently on its lateral aspect. The character of the area surrounding the external opening of the duct has already been discussed.

Certain variations are apparent when these organs are compared with the descriptions of *solifugus* from other localities. Moore ('99, pp. 130-131) found three spermathecal diverticula. He also found that the ampullæ of the two spermathecæ unite to form a short duct before joining the digestive tract on its dorsal side. No mention is made of unicellular glands on the duct. Eisen's description ('05, p. 60; Fig. 32b) agrees with that of Moore in almost every respect. However, his figure shows, on one of the spermathecæ, one diminutive and three equally developed diverticula, indicating a possible variation, although no mention is made of it in his description. Emery's original description of *solifugus* ('98a, pp. 110-111) contains the following statement: "I ricettacoli del seme non communicano con l'intestino; sono in continuità l'uno coll', altro ed hanno ciascuno, alla base della loro ampolla, due o tre diverticoli." His more complete paper ('00b) corroborates this

statement. It appears, from the above, that specimens with as few as two spermathecal diverticula were found. The reported absence of the communication of the ampulla with the digestive tract may be an error as has been suggested by Moore. Emery ('00b, p. 230) re-examined his material and found no connection but states that the spermathecæ lie in close contact with the intestine and points out the possibility that his single sectioned specimen might be not fully mature or abnormal.

Pigmentation.—All of the specimens from Mt. Rainier are deeply pigmented. Microscopic examination of sections of all parts of the body shows that the hypodermis bears a heavy load of minute, dark brown, non-staining pigment-granules, especially in the outer ends of the cells. This pigmentation extends to the internal organs. The chloragog cells, which first appear in IV and are present throughout the remainder of the body, are heavily loaded with pigment. It also occurs in the glands surrounding the bases of the setæ, in the lymphocytes, in the lining of the buccal cavity and the pharynx, in the spermathecal duct, in the lining of the penial invagination, in the nerve cord, and in the brain. It will be noted that this distribution of pigment corresponds closely with that described by Moore ('99, p. 127) for specimens of *solifugus* from Alaska. Eisen ('05, pp. 59, 60) states that the pigment is distributed in the body-wall and also in most of the internal organs "even in the ganglia and the brain" but does not specify further detail.

Summary of Comparisons.—The variety, *rainierensis,* differs from the Alaskan specimens of *solifugus* in the following respects: (1) the smaller number of setæ per bundle, (2) the absence of enlarged setæ on XI, (3) the origin of the dorsal blood-vessel in XIII-XIV, (4) the concavity of the posterior margin of the brain, (5) the constant presence of only two diverticula on the spermatheca and the independent opening of each spermatheca into the lateral wall of the digestive tract, (6) the shorter accessory glands, the smaller number of atrial glands, the larger number of multicellular glands within the penial bulb, and the straighter spermiducal funnel, and (7) the complete enclosure of the sperm sacs and sperm ducts by the ovisac. All of these differences seem

to be constant and are sufficient to raise the question as to whether they are too wide to be considered within the range of intra-species variation. However, they are differences of narrow margin and when compared with the sum total of the points of agreement with *solifugus* as described, the writer is convinced that the Mt. Rainier material is not a distinct species but can be considered only as a new variety.

BIOLOGICAL NOTES

As stated before, all of the information concerning the living specimens has been furnished by Mr. Flett. He found *Mes. solifugus* var. *rainierensis* abundant on the higher snow-fields and glaciers of Mt. Rainier in early summer. The collection which has furnished the material for the preceding description was made on June 17, 1915, at an altitude of 7,500 ft. Nothing is known concerning the winter or early spring conditions since at those seasons collections at such heights are not possible. These worms occur on snow-fields which seldom thaw during the summer and they evidently pass the entire existence, generation after generation, in the snow and ice. Mr. Flett states that on one occasion he has seen what he thought was this worm at an elevation of only 6,000 feet where the snow melts and grass and flowers grow in profusion during three or four months of the year. However, this was an unusually low altitude for these worms since they occur regularly and more abundantly much higher up the mountain on the permanent snow-fields and on the snow and ice of the glaciers. The writer has not had the opportunity of studying specimens from an altitude as low as 6,000 feet, but if the worms seen at that level are *solifugus* var. *rainierensis,* as Mr. Flett thinks they are, it appears that those individuals which chance to be developed at the unusually low levels must pass a part of the life history in midsummer on or in the ground.

On the glaciers, these worms coil up so as to appear as small spherical black dots on the snow or solid ice and it requires a considerable exposure to sunshine to warm them up to the active stage. According to the observations of Bryant (Moore, '99, p. 134), the specimens of *solifugus* on Malaspina Glacier, Mt. St.

Elias, "remain on the surface during the night; but when the sun appears in the morning they again burrow into the snow". This does not agree with the observations of Mr. Flett for the variety *rainierensis* since he has noticed no tendency on the part of the worms to avoid sunlight, the warmer the day the more active they become, this activity being manifested on the surface. The period of greatest activity is usually from the middle of the afternoon to about five or six o'clock.

No data on the associated life are available except the statement by Mr. Flett that snow algæ ("Sphærella nivalis") occur in great abundance and that spiders and snow-fleas (Collembola) are present.

The question of the food of a worm living in such a habitat is of considerable interest. Obviously, in the case of those individuals living on the permanent snow-fields and the ice of the glaciers, the number of substances serving as food are extremely limited. Emery ('00b, p. 226) found the contents of the intestine of Alaskan specimens, especially in the posterior part, to consist of "very fine crystalline mineral detritus, which seems to be the ordinary food of this worm". An examination of the intestinal contents in the Mt. Rainier specimens yielded practically no definite data. A certain amount of what seems to be fine, angular, mineral particles is present. However, the conspicuous content was a more bulky material, which the writer was unable to identify. In some respects, it has the appearance of partly disintegrated vegetable matter. This material was found in every specimen examined and evidently represents a part of the usual food.

GENERAL CONSIDERATIONS ON SNOW-FIELD AND GLACIER WORMS

Temperature Relations.—A striking thing about the environment of these enchytræids is the very low temperature of the medium in which they live. They exist and carry on their life processes under freezing temperatures and in a medium of snow and ice. Species, such as *Mes. gelidus,* which regularly occur at an altitude below the limit of permanent snow-fields evidently pass

a part of the life history on or in the ground, but aside from the midsummer months they are covered with snow and live in the latter or else in the earth beneath it. In either case, they are passing the greater part of the year in cold conditions, appearing in the melting snow in early spring. On the other hand, *solifugus,* which regularly inhabits the permanent snow-fields and the ice of the glaciers, spends its entire existence, generation after generation, under these conditions. Apparently, it must deposit its eggs in the snow, on the ice, or in the small pools of ice water which sometimes occur on the surface of the lower parts of the glaciers, and the young worms must be able to withstand the rigid conditions and successfully solve their problems of maintenance.

Pigmentation.—Nothing is known concerning the rôle of the large amount of pigment. Reference has already been made to the speculative discussion of this problem by Moore ('99, pp. 135-142). It may be related to the maintenance problems of heat or light, or both, but until some careful observations and experiments are made no definite conclusions can be drawn. If such pigmentation were confined exclusively to glacier forms the circumstantial evidence might be stronger in favor of a theory that it is an adaptation to some of the factors peculiar to that environment, perhaps light and temperature, but the fact that species other than glacier forms are known (*Mes. harrimani* Eisen, *Mes. obscurus* Eisen, *Mes. maculatus* Eisen, and others) which possess similar pigmentation throws some doubt on such an assumption. If it be true, as is suspected in some cases, that the younger stages of these glacier worms are not pigmented, a critical study of the life history may be necessary to the accurate solution of this problem.

Other Snow-field and Glacier Worms.—It is possible that future investigations of the northern glaciers and the arctic snow-fields will reveal still other enchytræids which occupy these frigid habitats and extend the knowledge of the distribution of the species already known. Certain arctic explorers make mention of the presence of "worms" on the snow and ice and while no hint is given of their identity, it is quite possible that they are enchytræids. Mr. Flett states that he found a snow-worm in the Olympic Mountains which occurred in enormous numbers, making the snow black,

and which resembles *Mes. solifugus* var. *rainierensis* in size and general appearance, but since material has not been secured its identity is unknown. Among the collections from Mt Rainier, there is at least one other enchytræid which appears to be distinct from those described in this paper but has not been carefully studied.

Thus far, all of the known glacier worms belong to the genus *Mesenchytræus*. While our knowledge concerning the geographical distribution of *Enchytræidæ* is incomplete, it appears fairly certain that the family is one of temperate and frigid distribution. Ude ('01, p. 23) found, among other things, that available data showed that "Die Gattungen *Mesenchytraeus* und vielleicht *Henlea* (vergl. *H. ventriculosa* (Udek.) lassen in ihrer Verbreitung Cirkumpolarität vermuten." Certain other genera (*Bryodrilus, Lumbricillus,* and others) have representatives in the arctic zone but none of them seem to have been reported as living continuously in snow and ice. Whether this habit is confined to *Mesenchytræus* is a problem for future investigation.

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EXPLANATION OF PLATES

Abbreviations

ac. gl.,	accessory gland.
atr.,	atrium.
atr. gl.,	atrial glands.
cut.,	cuticula.
ec. op.,	ectal opening.
hyp.,	hypodermis.
in. pen. gl.,	intra-penial glands.
lum. amp.,	lumen of ampulla.
lum. div.,	lumen of diverticulum.
ov's.,	ovisac.
pen. b. i.,	penial bulb invagination.
pen. ch.,	penial chamber.
pen. gl.,	penial glands.
pen. po.,	penial pore.
r. m.,	retractor muscle.
sp. d.,	sperm duct.
sp'r.,	spermatheca.
sp'r. d.,	spermathecal duct.
sp. s.,	sperm sac.
I-XXXV.,	somites.

Plate XIV

Mesenchytræus gelidus

Fig. 1. Diagram of XI–XXXV, showing position and extent of ovisac, sperm sacs, spermiducal funnels, and sperm ducts. Broken lines indicate omission of somites.

Fig. 2. Diagram of I–X, showing extent of the exceptionally large spermathecæ. The broken lines across spermathecæ in posterior part of VIII indicate most anterior observed termination of these organs.

Fig. 3. Longitudinal section through ectal region of spermatheca.

Fig. 4. Lymphocytes, indicating abundance of pigment-granules in cytoplasm.

Fig. 5. Chloragog cells. Pigment-granules distributed through cells.

Fig 6. Longitudinal section through ectal opening of spermatheca, showing unicellular glands which occur in connection with end of spermathecal duct.

Plate XV

Mesenchytræus gelidus—cont.

Fig. 7. Spermatheca.

Fig. 8. Spermatheca.

Fig. 9. Setæ. Bundle from ventral row.

Fig. 10. Brain.

Fig. 11. Penial bulb and associated structures.

Figs. 12–13. Spermathecæ from one specimen, drawn to same scale, showing a rather exceptional form of variation in development.

Fig. 14. Nephridium.

Figs. 15–17. Diagrams of different forms of spermiducal funnel.

Fig. 18. Nephridium.

Plate XVI

Mesenchytræus gelidus—cont.

Fig. 19. Longitudinal section through penial bulb.

Plate XVII

Mesenchytræus solifugus var. *rainierensis*

Fig. 20. Penial bulb as it appears in transverse section of body.

Fig. 21. Spermatheca.

Fig. 22. Brain.

Fig. 23. Spermiducal funnel.

Fig. 24. Setæ.

Fig. 25. Nephridium.

Fig. 26. Penial bulb and associated structures.